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# SUMMARY REPORT

## Investigation of the Biological Effects of Microwave Radiation

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## INTRODUCTION

The present report is to summarize the research work conducted under the subject contract. The object of this work was to obtain a fundamental understanding of the physical and physiological quantities and relationships involved in the irradiation of biological subjects with microwaves and to aid in establishing human tolerance values.

Prior to the contract, many observations had been made relative to the heating of tissue by microwaves, and several investigators had conducted experimental studies with animals using microwave sources available from World War II. With new microwaves sources available or being designed for various frequencies and power levels, a more comprehensive program appeared to be necessary. This program was to include a number of university research groups working on various aspects of the problem.

The work at Tulane University commenced with exploratory exposures of animals followed by an analysis of the physical parameters involved, measurement of physical quantities, and an experimental physiological program consisting of groups of exposures with comprehensive tests to indicate changes.

## DESCRIPTION OF RESEARCH

The initial work was exploratory, consisting of exposures of various animals types using 10 cm surplus equipment. Subsequently, 3 cm equipment was obtained and measurements of temperature increases in tissue as a function of field power density and exposure time were obtained.

Using additional measurement equipment, the complex dielectric constants[1] of various tissues were obtained. Following the construction of a microwave anechoic chamber, scattering measurements were obtained for infinite half-planes and spherical shapes at 3 cm.

Concurrently, a histopathological survey was obtained using mice in an attempt to pinpoint effects occurring at power levels close to the permitted value of 10 milliwatts per square centimeter.[2] In order to examine possible non-thermal effects, variations were used in the ratio of instantaneous to average power for fixed values of average field power density. In the groups irradiated at 45 milliwatts per square centimeter with 3 cm radiation for five minutes leucopenia and leucocytosis were found to occur though this was not observed in the controls. Weight data indicated differences in both growth rate and final weight associated with radiation. In addition, differences were noted in blood plasma volume distribution. Mice irradiated for periods longer than 5 minutes died shortly thereafter.

Weight changes were also noted in experiments conducted with a 10 cm source using mice. Subsequently, a more comprehensive program was run to check on possible growth rate changes at a power density of 10 milliwatts per square centimeter using 10 cm equipment. This study indicated no significant effect on growth rate due to exposures at this power density level and wavelength.[3]

In order to study biological effects without major increase in tissue temperature, experiments were run with pre-chilled, cold-blooded animals. By using cooling air and thermostating at a selected temperature of 20°C, lizards were maintained in a 3 centimeter radiation field of 45 milliwatts per square centimeter for periods of up to two hours without apparent damage.

To examine possible changes in biological activity associated with the orientation of the microwave field, exposures were made of the ion transport across frog skins. All changes observed could be reproduced by heating of the ion transport cell.

An experimental apparatus was constructed for the study of dielectric saturation and denaturation of proteins at relatively high field strengths. The apparatus was not effective due to non-uniformities in the plates employed. This approach to an understanding of microwave effects was discontinued when it became apparent that a relatively large investment in equipment would be required.

Using the 3 centimeter equipment, apparatus was designed to study the electrical properties of a multiple layer complex dielective model in relation to computed values. The reflection and transmission properties of the multi-layer model were computed from single tissue electrical parameters obtained by several investigators by using the multiple layers as a complex transmission line. This approach was suggested by H. Schwan and has been outlined by J. Stratton. The computer studies were sponsored in part by the U. S. Air Force and the Computer Center at Tulane University. The Office of Naval Research has provided microwave equipment for the experimental phase of the work. At the present time this work is not complete.

## CONCLUSION

The research program sponsored has provided confirmatory support for the human tolerance value for microwave radiation of 10 milliwatt per square centimeter. At somewhat higher values of field power density, for example at 45 milliwatt per square centimeter with 3 centimeter radiation significant heating effects are observed with several animal types. No consistent damaging effects were observed at 10 milliwatt per square centimeter in the experiments conducted with 3 centimeter and 10 centimeter sources.

Various approaches have been used to find non-thermal effects of microwave radiation. No important non-thermal damaging effects have been found in the experiment at Tulane.

## References

[1] Baus, R.: A Method of Measuring the Complex Dielectric Constant of High Loss Materials in the Range of Centimeter Waves. Annual Progress Report (1955-1956), December 17, 1956, Contract N onr-475(03), Office of Naval Research.

[2] Investigations of the Biological Effects of Microwaves, Annual Report, June 30, 1957, Contract Nonr-475(03), Office of Naval Research.

[3] Investigations of the Biological Effects of Microwave Radiation, Annual Report, 1958, Contract Nonr-475(03), Office of Naval Research.